Overview
Associate Lab Director's Perspective

DOE-NP annual S&T Review of RHIC

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July 6-8, 2005

Office of Nuclear Physics
Exploring Nuclear Matter - Quarks to Stars

BROOKHAVEN NATIONAL LABORATORY
Brookhaven Science Associates

Contents

- RHIC overview
- Accomplishments of the RHIC program
- The Roles of BNL
- Core competencies at BNL
- Priorities, vision, outlook for the RHIC program

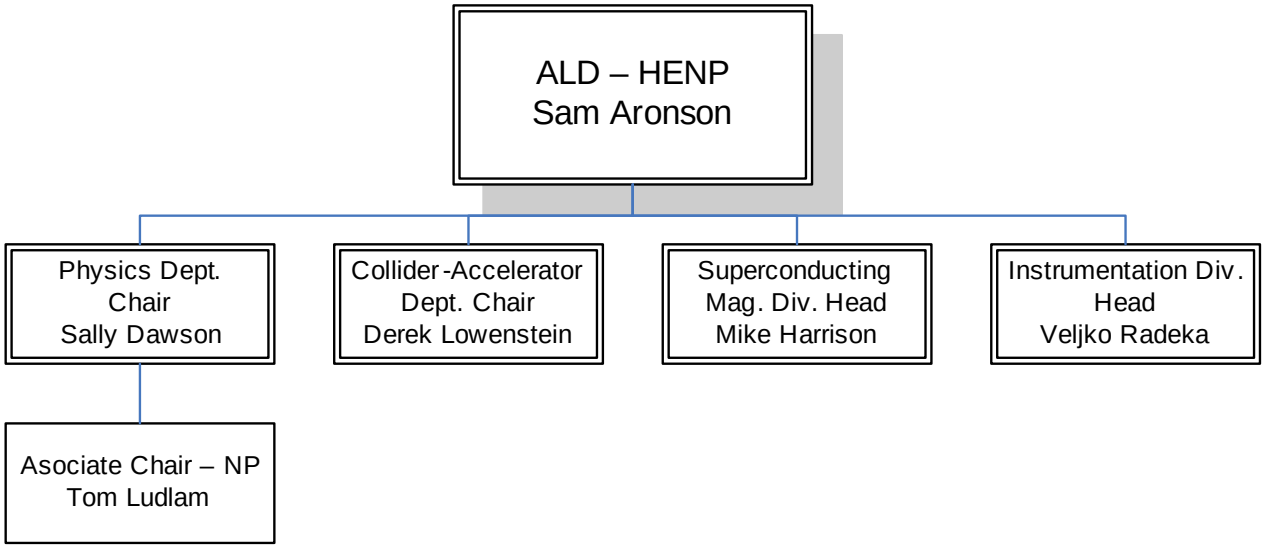
Structure of this Review

- Wednesday Morning
  - Laboratory perspectives, vision
  - Collaboration reports, outlook
- Wednesday Afternoon
  - Accelerator performance, upgrades
  - Detector plans, upgrades
- Thursday Morning Parallel Sessions
  - A: Accelerator R&D
  - B: RHIC Computing Facility Operations
  - C: BNL Scientific Program
- Thursday Afternoon
  - Theory programs, Users' perspective

The structure of the review as I see it

- Hybrid: S&T Review of the RHIC Program ⊗ Review of BNL performance in Research and Operations
- Somewhat entangled, but it mirrors the typical problem of a host laboratory
  - Balancing research and "customer" support
- This review will be most useful to me if it evaluates how well we achieve this balance

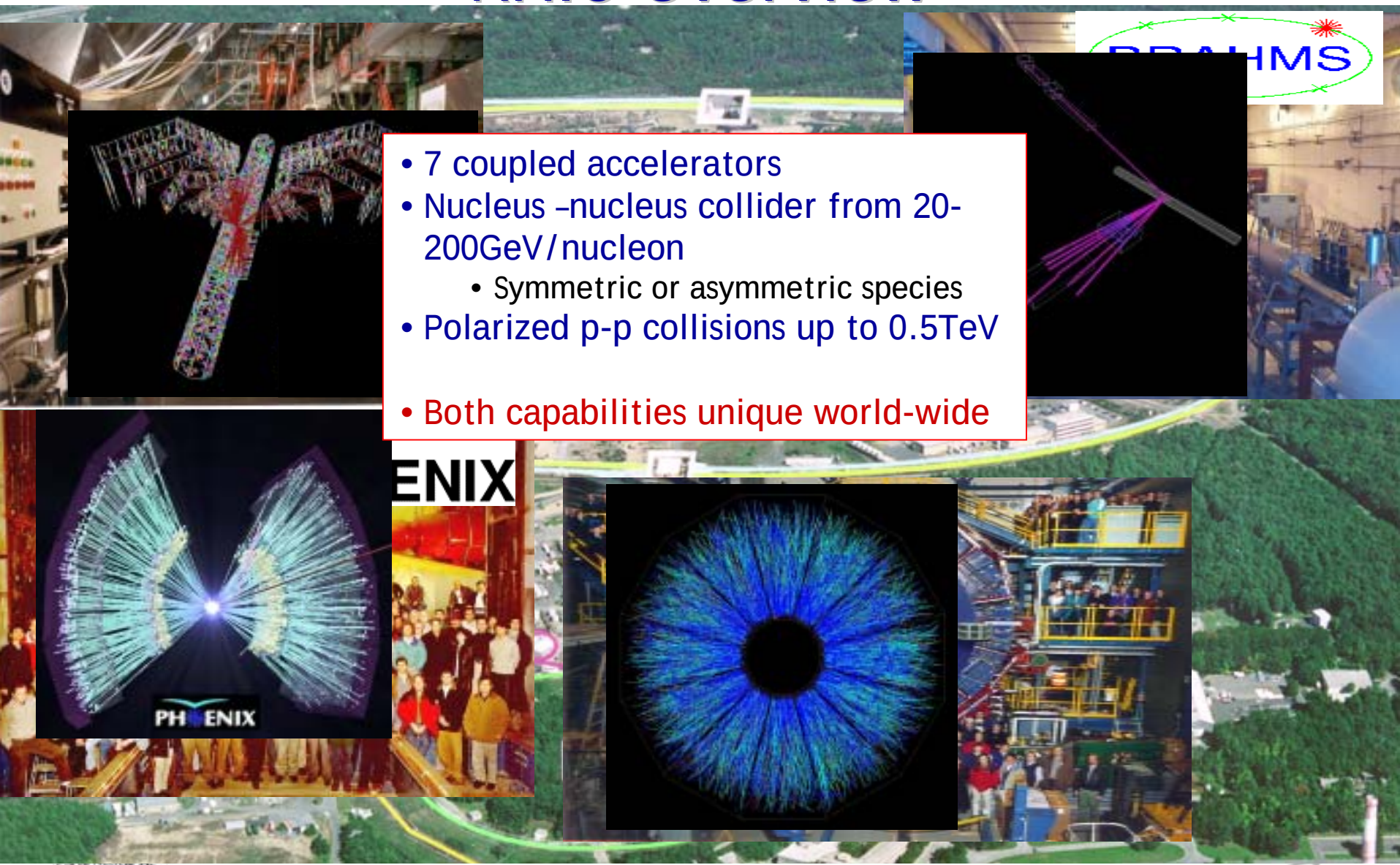
HENP Overview



HENP: 2 Departments, 2 Divisions, ~660 FTEs

- Some NP-funded activity in Chemistry Dept.
  - Also National Nuclear Data Center in Energy Sci & Tech Dept.
- Total BNL NP Budget Authority ~$150M/yr

RHIC Overview



- 7 coupled accelerators
- Nucleus –nucleus collider from 20-200GeV/nucleon
  - Symmetric or asymmetric species
- Polarized p-p collisions up to 0.5TeV

- Both capabilities unique world-wide

RHIC Program Accomplishments

- Five spectacularly successful annual runs
  - Physics discoveries: a new state of matter
  - Scores of refereed papers, thousands of citations
  - Machine performance meeting and exceeding goals
- Recently published peer-reviewed retrospectives on the first 3 years of heavy ion physics
  - *Nuclear Physics* ***A757*** (in print 8 August 2005)
  - Online http://www.sciencedirect.com/science/journal/03759474
  - Where are we in the discovery phase?
- Large Au+Au sample (Run 4) being analyzed
- Large Cu+Cu and polarized p+p samples (Run 5) in hand

The Roles of BNL

Research, Operations, Planning

Research

- HI research reviewed in 2004 against other labs
  - Very productive, leading groups in their collaborations
  - Fully integrated with experimental operations
  - Parallel Session C tomorrow
- Nuclear Theory and Spin groups to be reviewed in 2005, 2006 against other labs
  - Synergy with RIKEN BNL Research Center (RBRC): one of two major positive impacts of participation in RHIC from Japan (also US/Japan program via KEK)

Forefront experimental and theoretical research at BNL is vital to outstanding operations at RHIC

The Roles of BNL

Operations

- RHIC has met and mostly exceeded expectations
  - Integrated luminosity
  - Proton polarization
  - Energy scans
  - Development
    - pp @ $\sqrt{s_{pp}}$ = 410 GeV & 30% polarization in a few days!
- And has plans for operations improvement, e.g.
  - EBIS
    - NYS: Empire State Development Corp funds are expected to be available for infrastructure enhancement for EBIS

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NP

FY04 - FY05 Inflation Factor =					1.030	1.030	1.030	1.030	1.030
RHIC Facility Power Rate ($M)/week =					0.046	0.046	0.055	0.055	0.055
RHIC Beam Power Rate ($M)/week =					0.190	0.190	0.226	0.226	0.226
RHIC M&S ($M)/week =					0.200	0.200	0.200	0.200	0.200
Power Rate increase factor after FY05					1.190				
Version: June 29, 2005	Space Chg. (MII) Increments from FY05 PB by year ($M) =					0.7	2.0	2.0	2.0
S. Aronson, G. Rai	RHIC Base Power from FY05 by year ($M)=					0.0	0.1	0.1	0.1
New Power Rate	RHIC Fringe Increments from FY05 by year ($M) =					1.3	1.3	1.3	1.3
	Staffing decrement by year at $180K/FTE-yr ($M) =					0.0	0.0	4.0	4.0
Fiscal Year	2003 (FY03 $M)	2004 (FY04 $M)	2005 Est (FY04 $M)	2005 Est (FY05 $M)	2005 PB[2] (FY05 $M)	2005 BNL[2] (FY05 $M)	2006 (FY05 $M)	2006 Pres (FY05 $M)	2006 BNL (FY05 $M)
Cryo. Weeks/Yr	27	27	27	27	32	32	32	12	12
PHENIX									
Ops. Costs	6.0	5.9	5.9	6.0	4.1	4.1	4.1	3.8	3.8
M&S					1.3	1.3	1.3	0.5	0.5
R&D	0.1	0.5	1.0	1.0	1.0	1.0	0.7	0.5	0.5
Ops. Equip.	0.5	0.9	0.9	0.9	0.9	0.9			
Res. Equip.	0.0	0.0	2.5	2.6	0.0	0.0	1.4	1.4	1.4
			VTXb	VTXb	VTXb	VTXb	VTXb	VTXb	VTXb
STAR									
Ops. Costs	5.9	5.8	5.8	5.9	4.2	4.2	4.2	4.0	4.0
M&S					1.3	1.3	1.3	0.5	0.5
R&D	0.1	0.5	1.0	1.0	1.0	1.0	0.8	0.5	0.5
Ops. Equip.	0.5	1.0	1.0	1.0	0.7	0.7			
Res. Equip.	3.0	2.0	2.0	2.1	0.0	0.0	1.5	1.5	1.5
	BEMC	BEMC	TOF	TOF	TOF	TOF	TOF/MVTX	TOF/MVTX	TOF/MVTX
PHOBOS									
Ops. Costs	0.9	0.8	0.8	0.8	0.6	0.6	0.6	0.3	0.5
M&S					0.3	0.3	0.3	0.1	0.1
Ops. Equip.	0.0	0.2	0.2	0.2	0.1	0.1			
BRAHMS									
Ops. Costs	0.8	0.7	0.7	0.7	0.4	0.4	0.4	0.2	0.3
M&S					0.3	0.3	0.3	0.1	0.1
Ops. Equip.	0.0	0.1	0.1	0.1	0.0	0.0			
Summed Exps Ops. Eq.							2.2	2.2	2.2
RCF									
Ops. Costs	5.2	5.3	5.6	5.8	5.8	5.8	5.8	5.8	5.8
Ops. Equip.	2.0	2.0	3.4	3.5	2.5	2.5	2.0	2.0	2.0
C-AD RHIC OPS									
Ops. Costs	90.3	90.7	90.9	93.6	**76.2**	**78.2**	**79.5**	**76.2**	**76.2**
Base Power					3.8	3.8	3.8	3.8	3.8
Incr. Power					6.1	6.1	7.2	2.7	2.7
Base M&S					5.0	5.0	5.0	5.0	5.0
Incr. M&S					6.4	6.4	6.4	2.4	2.4
Total RHIC OPS					**97.5**	**99.5**	**102.0**	**90.1**	**90.1**
R&D	0.9	2.0	2.0	2.1	2.0	2.0	2.0	1.9	1.9
Ops. Equip./AIP	4.4	3.9	3.8	3.9	4.3	4.3	4.3	4.3	4.3
Res. Equip. (EBIS)[3]			2.5	2.6	0.0	0.0	2.6	2.6	2.6
Users/CAP	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Accel. + Expt Ops					116.7	118.7	121.2	106.1	106.6
eCooling R&D					2.0	2.0	2.0	1.9	1.9
Detector R&D					2.0	2.0	1.5	1.0	1.0
Total Cost (FY05 Dollars)					120.7	122.7	124.7	109.0	109.5
Total Cost with Inflation						122.7	128.1	112.0	112.6
Total Budget						121.6	120.4	112.1	112.1
Difference						-1.1	-7.7	0.1	-0.5
PHOBOS Terminated (Reduction Factor)							1.0	0.5	1.0
BRAHMS Terminated (Reduction Factor)							1.0	0.5	1.0
STAR Terminated (Reduction Factor)							1.0	1.0	1.0
PHENIX Terminated (Reduction Factor)							1.0	1.0	1.0
Staff Reduction							0	-22	-22
People Cost					96.2	96.2	95.9	95.9	94.3
Power					9.9	9.9	11.1	6.6	6.6
M&S					14.7	14.7	14.7	6.5	6.6
Inflation costs (excl. power)						0.0	3.4	3.1	3.1
Reserve/Deficit						-1.1	-7.7	0.1	-0.5
Total					120.7	121.6	120.4	112.1	112.1

Planning: Funding scenarios

Scenarios addressed for the NSAC subcommittee:

- FY 2005 program was 32 cryo-weeks and includes funding for R&D and upgrades
  - Good basis for an "optimized" long term program
- Constant effort funding starting with the President's budget in FY 2006 ⇨
  - Running across fiscal year boundaries (run every other year)
  - Limited investments in the future (upgrades slow down)
  - Reduced operations staff (40 FTEs in response to the 2006 President's budget)
  - Two small experiments cease operations
- Flat-flat funding at the FY 2006 President's budget level would effectively end the program in 5 years

The Roles of BNL

Scientific program planning

- Planning on all time scales with full community participation:
  daily, weekly meetings…annual, decadal and 20-yr plans
  - Beam Use Proposals → Program Advisory Committee
- Balancing of resources: running vs. investment
  - Running time (including split among energies & species);
  - Experimental support (including RCF & Infrastructure);
  - AIP; R&D
- Planning Spreadsheet co-maintained with DOE-ONP
- Other elements of the NP program
  - ME-LEGS, LE-neutrinos, LHC-HI, NNDC

Core Competencies at BNL

(Per "2005 Business Plan for BNL")

- Design, construct, and operate extraordinary facilities
- Advanced concepts of accelerators, detectors, magnets, and instrumentation
- Synchrotron radiation science and technology
- Imaging expertise
- Tera (peta)-scale computing

Core Competencies at BNL

(As relevant to the RHIC program)

- Design, construct, and operate extraordinary facilities **RHIC/AGS, ATF (today, Session A)**
- Advanced concepts of accelerators, detectors, magnets, and instrumentation
- Synchrotron ra **SMD (Session A), Instrumentation*** gy
- Imaging expertise
- Tera (peta)-scale computing

RCF (Session B, tomorrow), QCDOC

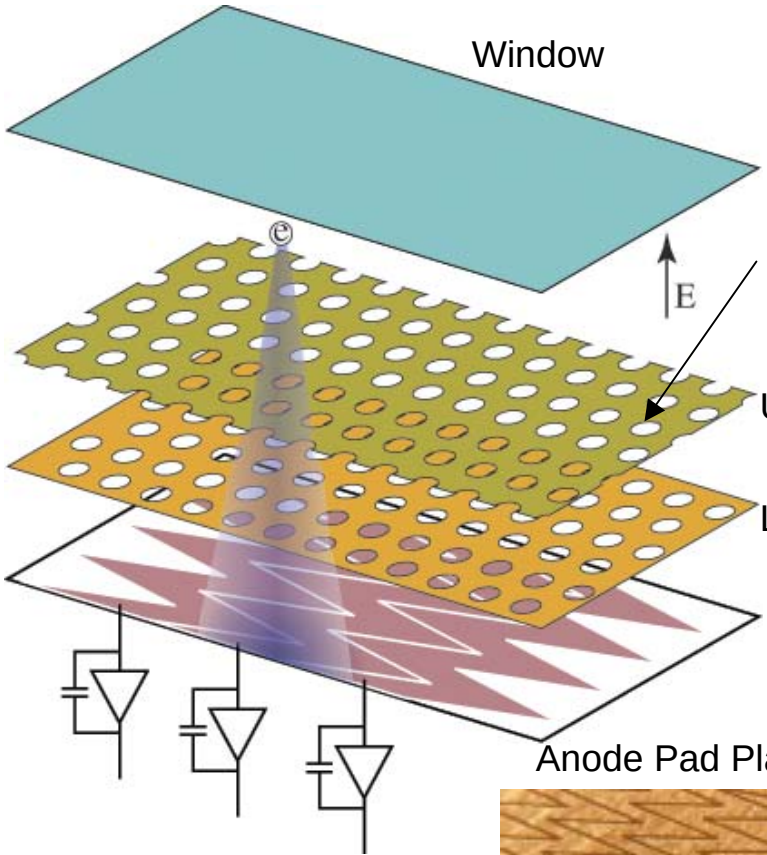
** Mentioned in this talk*

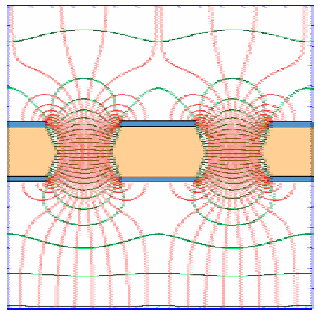
Instr. Div. Activities for RHIC

S = 1-2 years; M = 3-5 years; L = ≥ 5 years

	Time Scale:
Silicon Detectors	
• Vertex detectors	
- *low mass **M**onolithic **A**ctive **P**ixel **S**ensors (MAPS)*	M-L
• PHENIX (RIKEN, spin physics)	
- *single sided 2d strip detectors*	S-M
• For all polarimeters (CNI and H-jet) at AGS/RHIC	
-thin window and large thickness detectors	S-M
Gas Detectors	
• *Small fine grained ("Micro") TPCs*	M-L
• *Gas Electron Multipliers*	M-L
Microelectronics	
• *Fine-grained detectors (TPCs, etc.)*	S-M-L
• *FPGA & DSP technology*	S-M-L
RHIC Beam Monitoring	
• *Digital Signal Processing - continuing development*	
Photocathodes	
• *Electron cooling at RHIC*	M
• *e – RHIC, GaAs → polarized electrons*	L

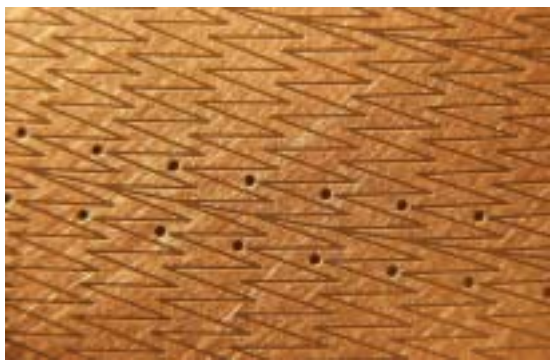
Interpolating Pad Readout for Gas Electron Multiplier (GEM)





Mounted GEM Foil on Frames

Prototype TPC with 10cm drift depth



GEM R&D reported by Bo Yu, et al. at IEEE NSS

Electron Source Development for E-Cooler (with CAD)

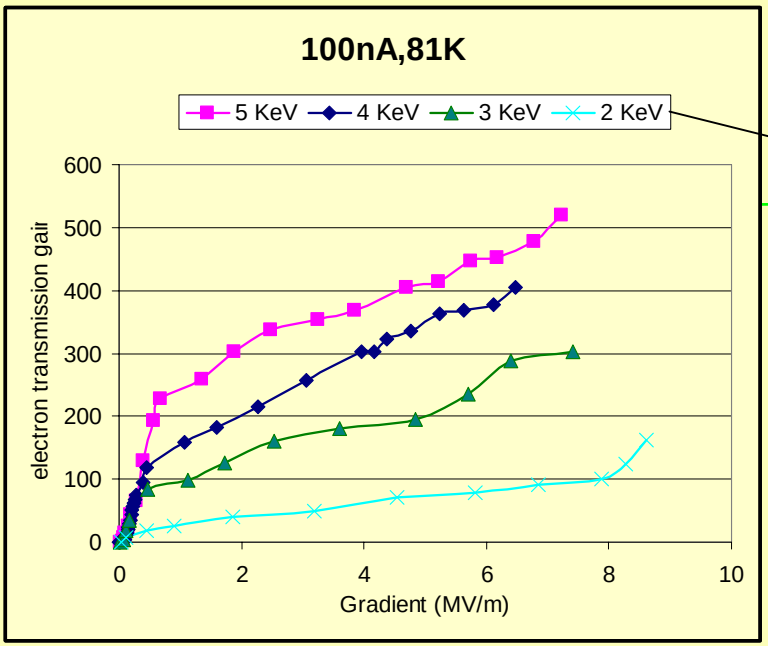
Diamond Secondary Emitter

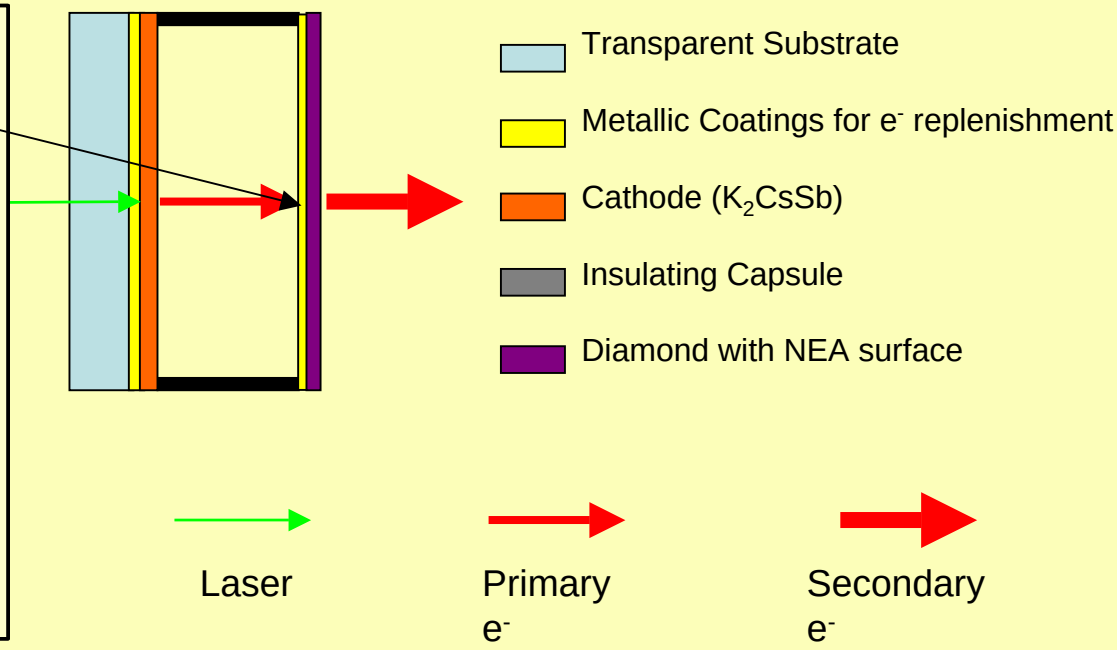
Diamond Test Chamber

Principle:

- Obtain 10mA primary current from a transmission photocathode
- Accelerate the primary electrons to a few keV
- Generate secondary electrons with a gain of 100+
- Transport electrons through diamond and into vacuum via specially prepared Negative Electron Affinity surface

Entire system is a sealed capsule – avoid contamination of cavity by Cesium from cathode, and improve lifetime, reduce laser power





Priorities, Vision, Outlook

The #1 priority for Nuclear Physics at BNL, present and future, is ***RHIC***

- Present and near-term:

Exploit the scientific opportunities at RHIC

- Enormous gains in knowledge to be made (in A+A and Spin) starting NOW with near term upgrades and incremental improvements
  - Luminosity, polarization, DAQ, particle ID, η coverage
- Optimized operations
  - Running time vs. investment
- Research support
  - Experimental – Research & ops support, detector R&D
  - Theory support – including thermodynamics on the lattice

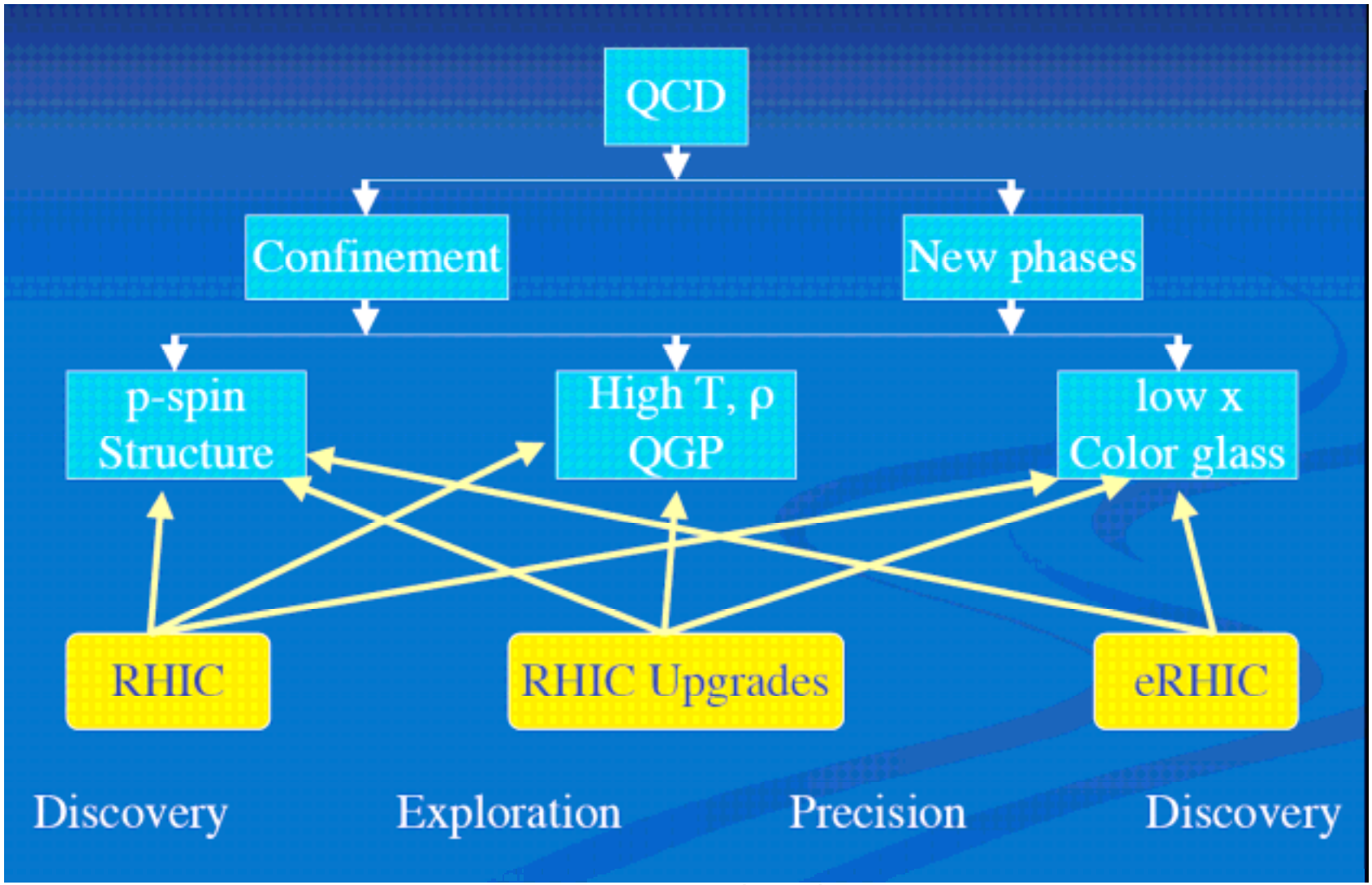
Priorities, Vision, Outlook

- Mid- to long-term:

Evolve RHIC into a (the) QCD Laboratory

- Address the compelling questions in QCD revealed by the discoveries at RHIC
  - Involve the RHI, Spin and DIS communities and in articulating the future science of RHIC and eRHIC

QCD Laboratory



RHIC Upgrade Science

QCD at High T and ρ	Is there a QCD **Phase Transition** to QGP; what are its properties? **Thermalization**: How do we evolve from a low-entropy initial state to a maximal entropy state on short time scales? **Deconfinement**: Do the degrees of freedom in the initial state have deconfined color charges? **Chiral Symmetry**: Is chiral symmetry restored at high T and r?
QCD at High E, Low x	What is the nature of **gluonic matter** in strongly interacting particles? Is this gluonic matter a **CGC** and is it the source of QGP? Is the **low-x structure of nucleons** in nuclei different from that of free nucleons?
QCD & Hadron Structure	How do gluons contribute to the **proton spin**? What are the u, d, s **quark & antiquark polarizations** in the proton? What **orbital angular momentum** is carried by the partons in a proton? What role does **transverse spin** play in QCD?

Priorities, Vision, Outlook

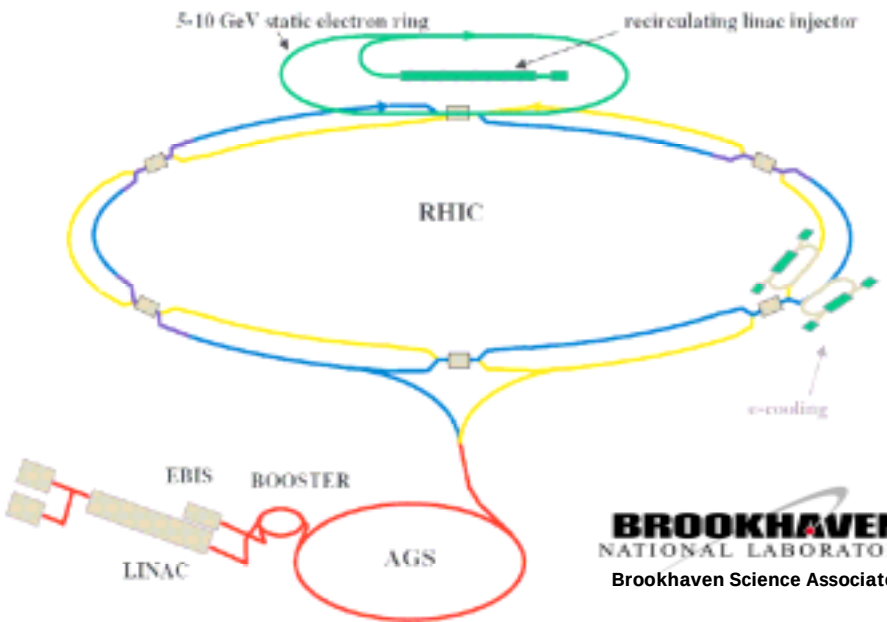
- Mid- to long-term:

Evolve RHIC into a (the) QCD Laboratory

- Address the compelling questions in QCD revealed by the discoveries at RHIC
  - Involve the RHI, Spin and DIS communities and in articulating the future science of RHIC and eRHIC
- R&D/investments → the tools and techniques needed to address the questions
- Sell the case to the NP community
  - NSAC Long Range Plan of 200X

RHIC → RHIC II/eRHIC

- Critical technologies (principally electron cooling) enable both RHIC II and eRHIC
  - Higher integrated luminosity through longer luminosity lifetime
- RHIC II
  - An additional order of magnitude in average luminosity (beyond near term incremental increases)
  - Detector enhancements
- eRHIC
  - Electron ring or linac
  - New detector



The Challenge

- Budget constraints on all time scales
  - Operations – big facilities have a big leverage factor on the last $ that comes in the door – *for example:*
    - FY06P: -8% → 60% cut in running, 10% RIF, loss of 2 smaller experiments, ~no R&D
    - As we told the Tribble subcommittee
      - **Constant effort** after FY06P → ~50% utilization of RHIC
      - **Flat-flat** funding after FY06P → "lights out" before 2010
  - Facilities - big upgrade, evolution (or decommissioning!) – look out of reach in present budget climate
- So: how to start down the ($700M) path to QCD Lab?
  - The FIRST STEP: QCD community would have to unite around it
  - Need continued congressional support for ↑science funds

Issues

- Action Items from last year's S&T Review
  - BNL should prepare a document that articulates its research plan for the ***RHIC spin physics*** program. A copy should be submitted to DOE by January 31, 2005
    - **Done**
  - The Magnet Division should prepare a report that identifies the level of resources and costs needed to support RHIC operations. A copy should be submitted to DOE by January 31, 2005
    - **Done but apparently not submitted (hand-off problem)**
    - **Available now (copies provided this morning)**

Summary

- RHIC's success has made BNL a world center for
  - Heavy Ion Physics
  - Spin Physics
  - Nuclear Theory (high T, high ε, high E, low x)
  - Accelerator science
- A clear (non-trivial!) path leading to a QCD Lab
  - $A+A, p+A, p+p, e+p, e+A$
  - New detector capabilities, higher luminosity and polarization

This path has ***discovery potential*** every step of the way!